A new tool for the visualization of magnetic features on audiotapes

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ABSTRACT The visualization of magnetic features can be of forensic relevance in the field of tape authentication. The Research Institute for Material Science and Technology in Zelenograd, Russia, has developed crystals with magneto-optical properties which permit convenient, precise and non-destructive visualization of magnetic information. These crystals change their optical properties according to external magnetic fields. The magneto-optical effects may be used for developing images of the magnetic structure of any analogue or digital recording. In this paper, we first provide some theoretical background about several magneto-optical effects. Subsequently, two experiments on visualization effects that are based on different physical principles (Kerr Effect, Faraday Effect) are described. Selected forensically relevant features detected on analogue recordings are shown. Special emphasis is given to visual features that may be used for authentication purposes.

KEYWORDS tape authentication, visualization, magnetic features, magneto-optical effects, Kerr Effect, Faraday Effect

INTRODUCTION

One of the tasks within the field of forensic analysis of tape recordings is the visualization and interpretation of magnetic features on tapes. Track width and position, azimuth[1] of the recording head, erase head marks and other features can best be analysed by visualization of the corresponding magnetic traces. The interpretation of the results may in some cases help to show whether an evidential recording has or has not been made on a given recorder, or it may reveal certain manipulations of tampering or editing.

There are different methods of visualization. Various sprays and liquids (ferrofluids) with impressive qualities have been successfully used for visualization purposes for many years. However, anyone who has ever been confronted with authentication tasks requiring the use of sprays and liquids has also had to cope with their restrictions. Revealing the magnetic structure of a recording by means of these methods always entails problems like difficult handling, poor resolution, bad visibility on dark tapes and the danger of residual stains or even partial destruction of the tape. These disadvantages can be avoided by using a method based on magneto-optical effects. In this case, the direct application of liquid visualizers is unnecessary – the visualization takes place within a solid medium which is brought into direct contact with the tape.

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The medium has magneto-optical properties and assumes an image of the magnetic structures on the tape. In order to use this method, special indicator plates, ‘crystals’, are needed. Their construction differs according to the method used for visualization.

Type A Crystal

The type A crystal is intended for analysing the magnetic structure of an object by means of a polarization microscope. It consists of different layers, the most important of which is a bismuth-containing iron garnet film. The optical properties of this material change according to its magnetization. When placing the crystal on the surface of a recorded tape, its ‘particles’ (internal magnetic moments) are magnetized by the structure of the recording on the tape. Accordingly, when the crystal is moved along the tape, the particles adjust themselves continually. The magnetization within the crystal is a one-to-one image of the magnetization on the tape and can only be made visible in polarized light. As the crystal cannot be lifted from the tape without losing the image, its magnetization has to be analysed while it is in close contact with the tape. Since the tape is non-transparent, there is a light-reflecting mirror layer underneath the crystal’s magneto-optical layer so that the result of the visualization process can be analysed in the reflected light. The modulation of the reflected light according to the material’s magnetization is known as the Kerr Effect. Figure 1 gives an illustration of the principle.

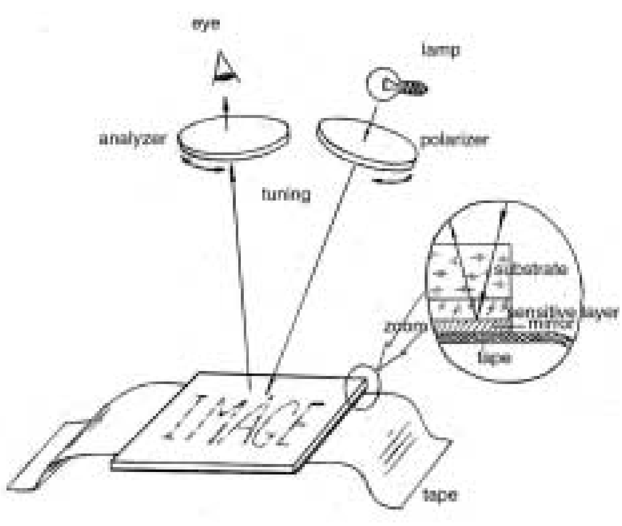

Figure 1 Schematic representation of visualization process by means of type A crystal

Type B Crystal

Type B crystals differ from type A crystals in the following respects: Unlike type A crystals, the internal magnetic moments within the magneto-optical layer do not react by simply being brought into contact with the tape. Instead, a special copying procedure is necessary. For this reason, the type B crystal is integrated into a device called 'MOA-KOF' (constructed in Zelenograd, Russia). The magnetic structure of the tape is imprinted into the crystal through an illuminating procedure with a defined amount of light and heat. After this procedure, the tape is removed and the resulting image may be analysed by means of transmitted light. Again, the light has to be polarized before and after its modulation by the internal magnetic moments within the analyser plate.

The modulation of the transmitted light according to the material's magnetization is known as the Faraday Effect. Figure 2 gives an illustration of the principle.

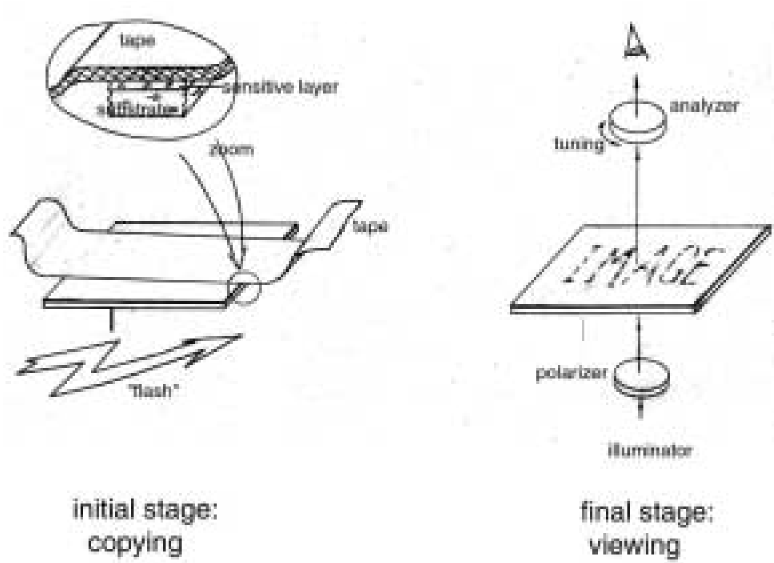

Figure 2 Schematic representation of visualization process by means of type B crystal

EXPERIMENTS

Experiment one

The first series of experiments investigated differences in the imaging of intensity (amplitude) variations when using both types of crystals. For these experiments, a DAC (Digital Audio Corporation) MAP-1 signal generator was used to generate two different sinusoid signals (1 kHz and 1.25 kHz) which were recorded on two channels of an analogue cassette tape, side A. The recording was made on a Sony K990 ES tape recorder, and the recording level was kept at 2 dB. The 1.25 kHz tone was recorded on the left channel. Its intensity was kept fixed at +6 dB on the output level meter of the MAP-1. The intensity of the 1 kHz tone on the right channel was varied from +6 to -34 dB: +6 dB, -4 dB, -14 dB, -24 dB, -34 dB. The question we addressed was whether and to what extent these variations in intensity could be reproduced by the visualization process using the type A and B crystals. The regions on the tape that were to be visualized were found by playing the tape on a cassette recorder. The tape was then pulled out of the cassette shell and the region of interest was placed under a polarization microscope, the recorded side facing upwards. A type A crystal of approximately 1 x 1.5 cm (standard size) was placed on the tape surface. Both tape and crystal were cleaned with pure alcohol beforehand so that dust particles would not impede optimal contact between tape and crystal. On occasion it was also necessary to optimize contact by pressing down the crystal. When the visualization result was satisfactory, the picture was transferred to a PC via a Zeiss 'AxioCam' camera and stored on hard disk.

Before progressing to the resulting images, however, it is necessary to understand the location of recording tracks on tapes generally.

Figure 3 shows the positioning of tracks on a tape recorded in mono on both sides.

Figure 4 shows the location of the tracks for a tape recorded in stereo format on both sides.

Plates 1 and 2 show the device and experimental setup.

Pictures of all the intensity variations were taken.

Plates 3 to 7 show parts of each of the tracks, one of them differing with the intensity variations, the other one remaining stable. It may easily be seen that the pictures show not only the signals themselves but also the decreasing intensity of the 1 kHz tone. At an intensity of -24 dB the signal is hardly visible. At -34 dB, the signal cannot be visualized at all.

Plate 3a shows the correlation between an oscillographic display and the visualization of a signal.

In the second part of this experiment, the same regions of the test tape were visualized on the 'MOA-KOF' with the type B crystal. The tape was placed on the crystal, which was fixed within a frame, the recorded side of the tape facing downwards. During the visualization process, activated by a control on the front face of the device, the tape was pressed tightly to the crystal for good contact. The resulting image within the indicator plate was viewed with the help of a polarizer, a microscope and a monitor and subsequently stored on hard disk via a Kappa CF 15/1 camera. It should be mentioned here that this combination is easier to handle than the combination of the type A crystal and a polarization microscope. Plates 8 and 9 show photos of the device and experimental setup. Plates 10 to 13 again show a part of each of the tracks, one of them differing with the intensity variations, the other one remaining stable. The visualization results however differ significantly from the results achieved with the Type A crystal, there being no obvious indications of intensity differences.

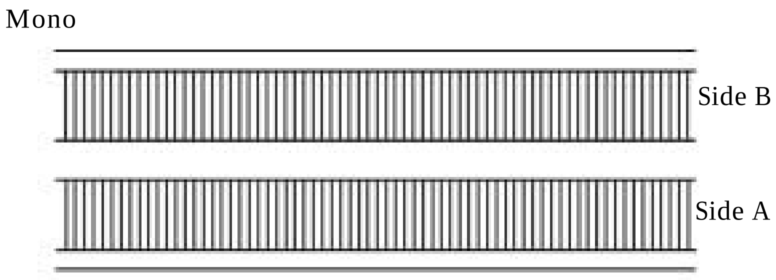

Figure 3 The positioning of tracks on a tape recorded in mono on both sides.

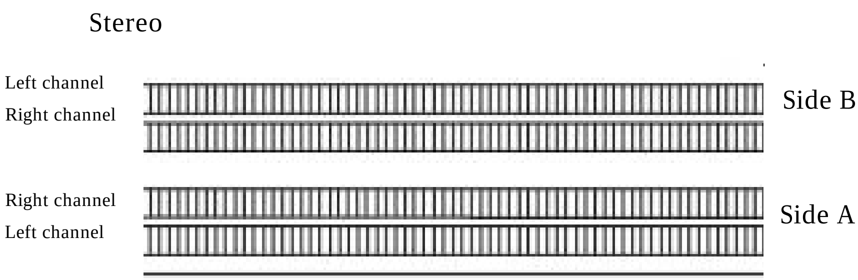

Figure 4 The location of the tracks for a tape recorded in stereo format on both sides

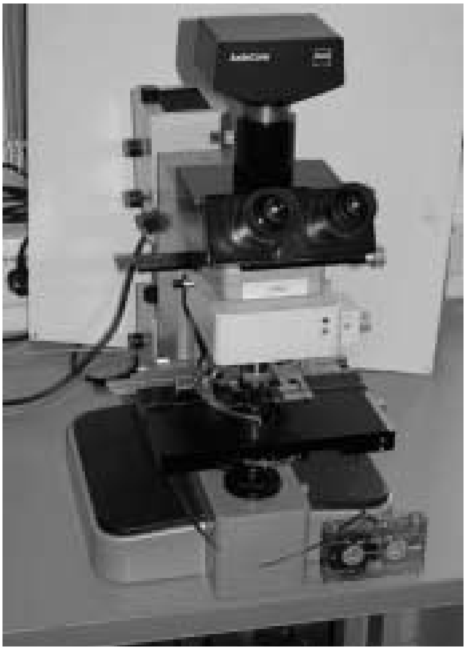

Plate 1 Type A crystal on cassette tape under polarization microscope, general view.

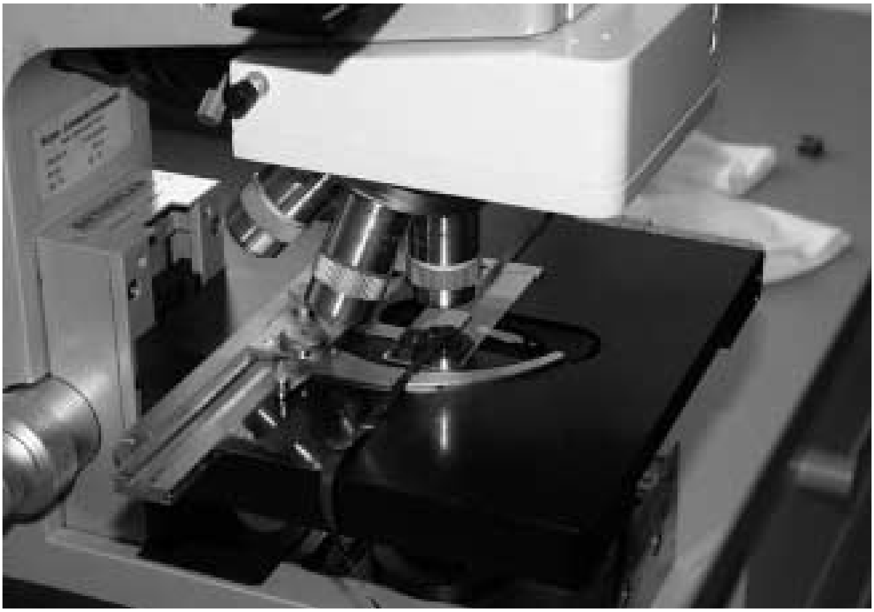

Plate 2 Type A crystal on cassette tape under polarization microscope, detailed view.

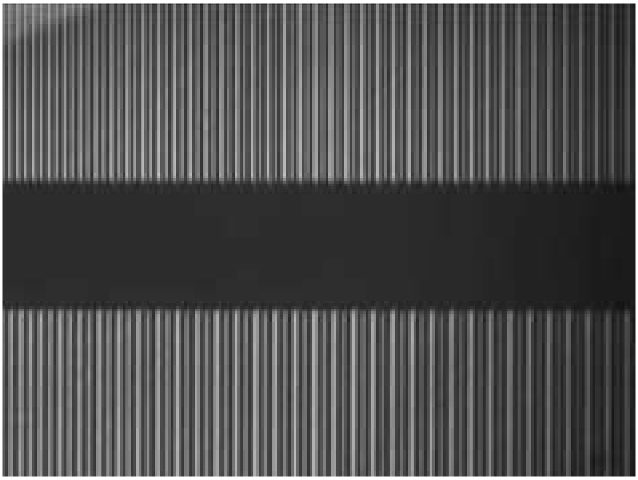

Plate 3 Image of section showing two channels of a stereo recording on analogue cassette tape, sinusoid signalgenerated at 6 dB for the right channel (1 kHz) and 6 dB for the left channel (1.25 kHz). Right channel in lower part of the picture. One period of the signal extends from one dark line to the next dark line, or from one light line to the next light line.

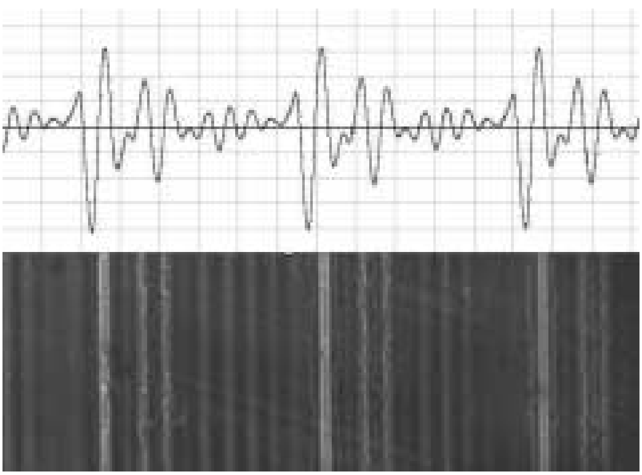

Plate 3a Vowel /a/, uttered by a male speaker. Oscillographic display above, visualized signal in the lower part of the picture.

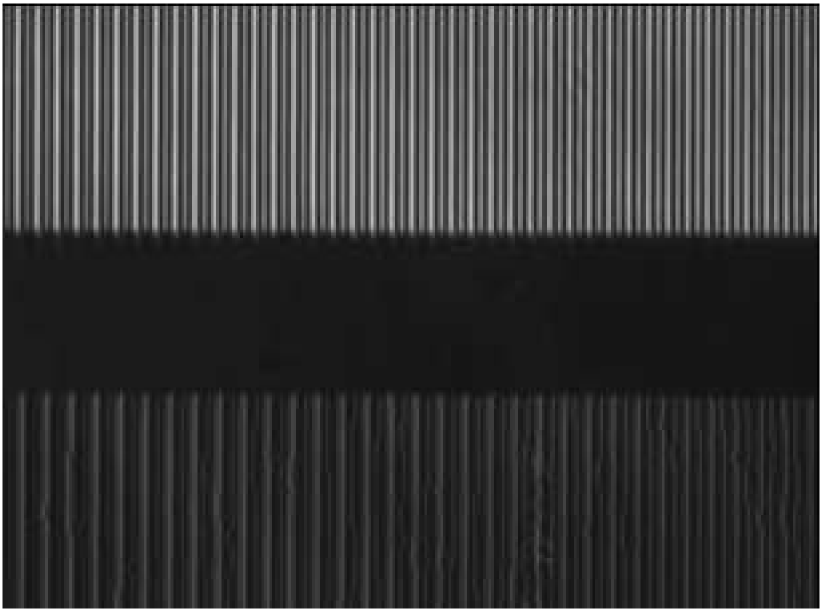

Plate 4 Same as plate 3, but signal on right channel generated at -4 dB. The visualization of the weaker signal contains artefacts which are difficult to avoid when using this type of crystal

Plate 5 Same as plate 3, but signal on right channel generated at -14 dB.

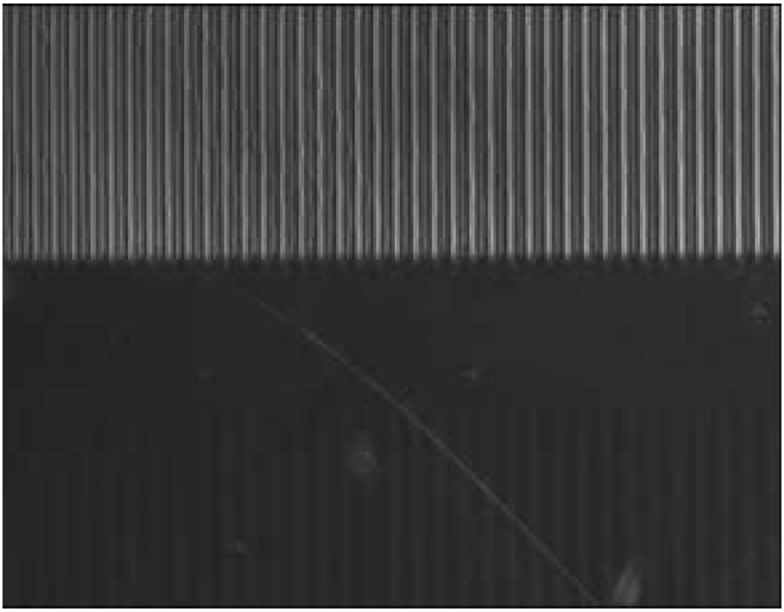

Plate 6 Same as plate 3, but signal on right channel generated at -24 dB.

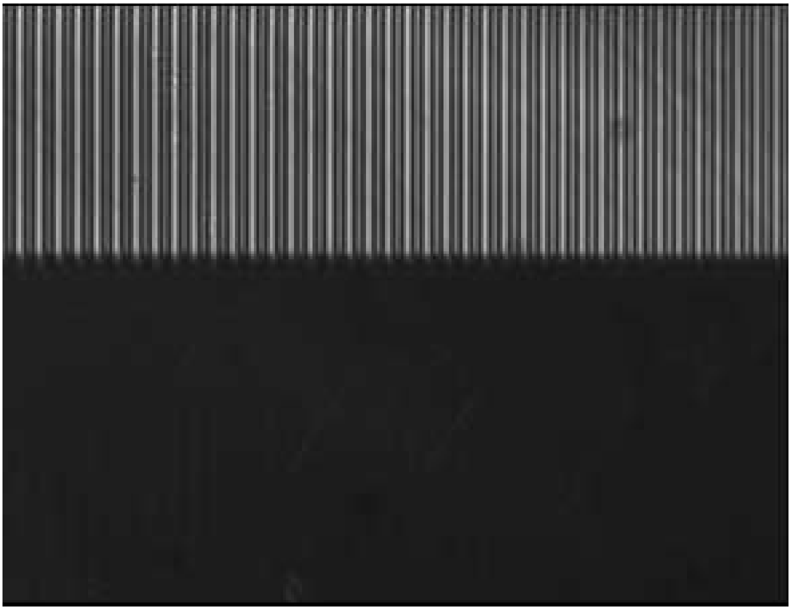

Plate 7 Same as plate 3, but signal on right channel generated at -34 dB.

Plate 8 "MOA-KOF" device with Leica microscope and Kappa camera, general view.

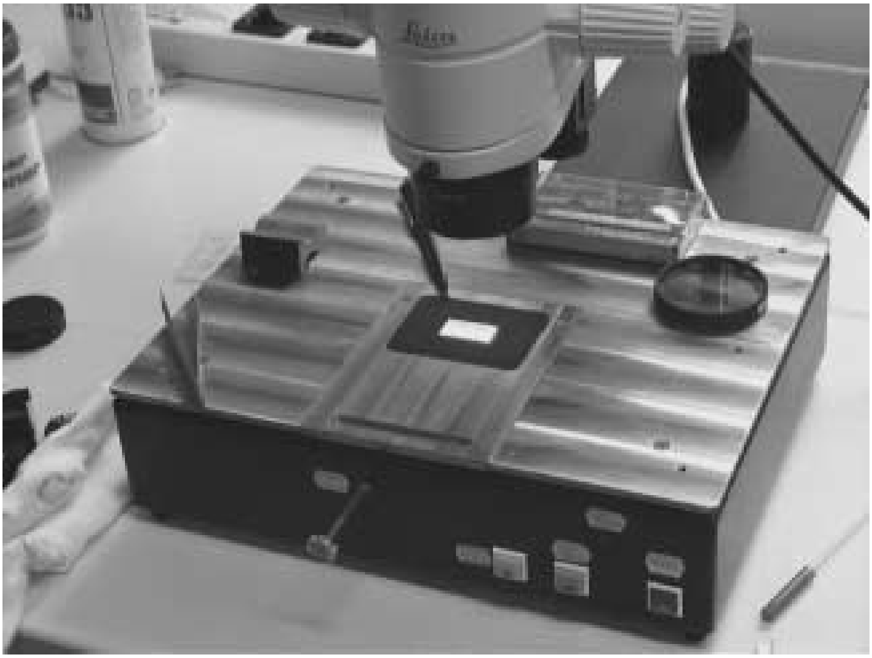

Plate 9 "MOA-KOF" device with Leica microscope above crystal (type B) within frame, illuminated from underneath. For analysis, a polarizer has to be placed on the illuminated field.

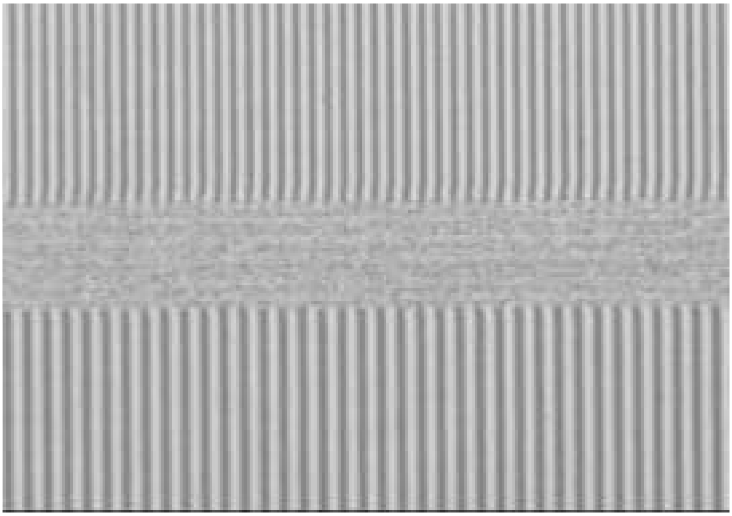

Plate 10 Two channels of a stereo recording on a cassette tape, signal generated at 6 dB for the left channel and –4 dB for the right channel (same as plate 4).

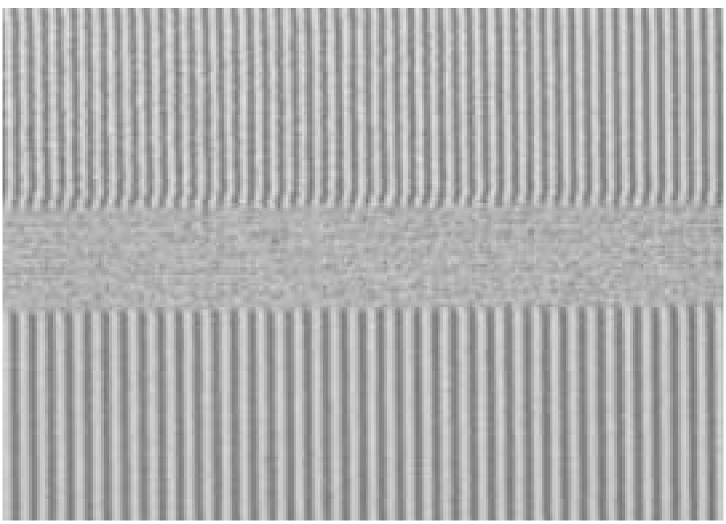

Plate 11 Two channels of a stereo recording – left channel 6 dB, right channel -14 dB.

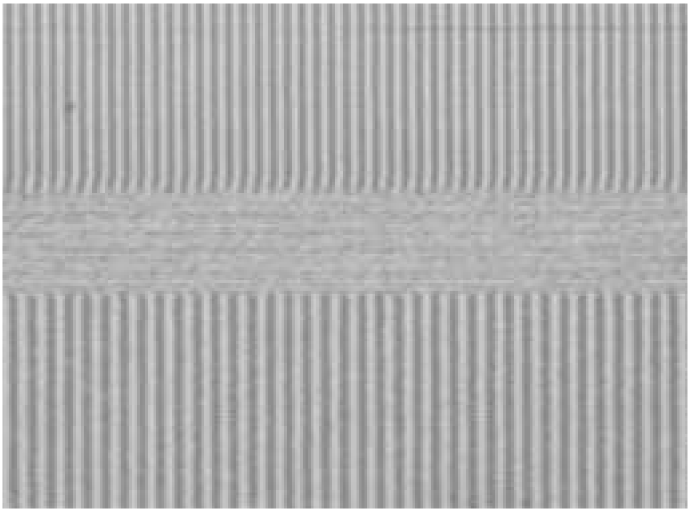

Plate 12 Two channels of a stereo recording – left channel 6 dB, right channel -24 dB.

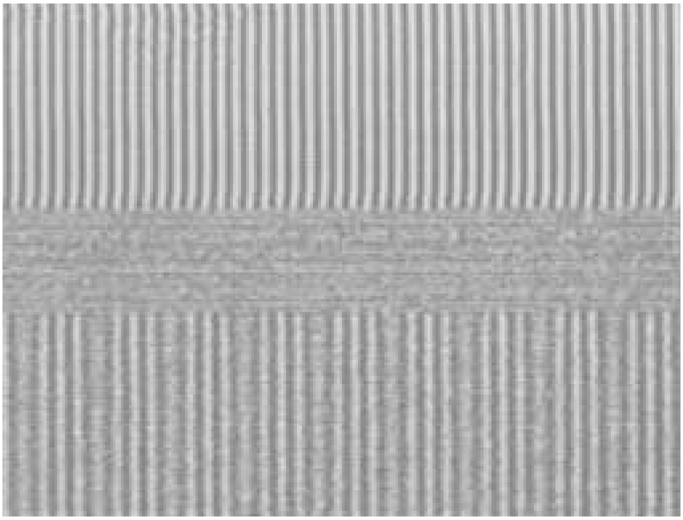

Plate 13 Two channels of a stereo recording – left channel 6 dB, right channel -34 dB.

RESULTS

The visualized signal within the type B indicator plate does not reflect the intensity changes in the same way as the type A crystal. For that reason the type A crystal may be preferred in cases where intensity variations play a role. On the other hand, the type B crystal may be chosen for visualizing signals of low amplitude. The lack of responsiveness with regard to intensity variations is compensated for by the advantage that even very weak signals can be made visible.

Experiment two

For reasons of easier handling and a bigger field of vision (the type B crystal measures approximately 3 x 1.3 cm), the second experiment was conducted only with the type B crystal and the MOA-KOF device. The purpose was to evaluate the possibilities of visualizing details of forensically relevant features like track width and position, record head azimuth and erase head marks. First, a series of test recordings was produced on 8 cassette recorders: Sony K 990 ES, Sony WMD 6C, Panasonic RQ 319, Panasonic RX 1900, Revox B 710, Uher CR 1600 (3 machines). All tapes used for the test were pre-recorded with a 180 Hz sinusoid on both sides and in stereo, using either the Sony K 990 ES or the Sony WMD 6C recorder. This signal was included simply in order to facilitate interpretation of the features to be viewed by indicating visually the position of the tracks. Next a 1 kHz signal was recorded on side A only. The recording was stopped after a few seconds and repeated twice with pauses of several seconds in between. Thus, each cassette contained three start and three stop events. Between a stop and the next start, the tape was transported via the 'play' function to avoid stop-start events which sometimes cause ambiguities in interpretation. Plates 14–27 represent a selection from the results (magnifications are between 5 x and 20 x).

Track width and position

Plate 14 shows several interesting phenomena. This recording has been made on a machine with a misaligned recording head: the tracks are not in the standard position but shift towards the edges of the tape. This can be seen in the decreasing width of the tracks near the edges (left channel) as they are cut off by the borders of the tape. The unrecorded space in the middle of the tape is too large. In addition, there seems to be a phase difference between the two channels. These peculiarities appear on all the cassette tapes that have been pre-recorded with this particular machine and appear to be characteristic of it.

Plate 15 shows a 180 Hz tone (side B of the cassette) that has been recorded on a Sony WM D 6C. Track width and position do not show any peculiarities. Side A has been over-recorded on the same recorder with a 1 kHz tone.

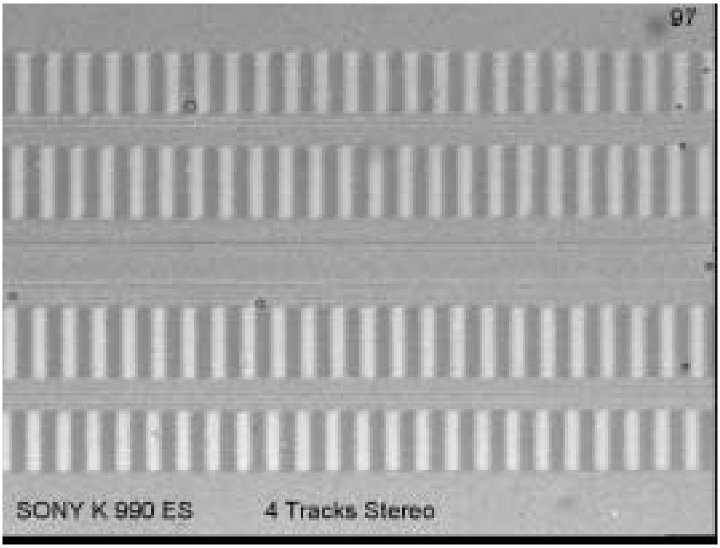

Plate 14 Stereo recording with Sony K 990 ES cassette recorder, 4 tracks, 2 tracks on each side, 180 Hz, side A in the lower part of the picture.

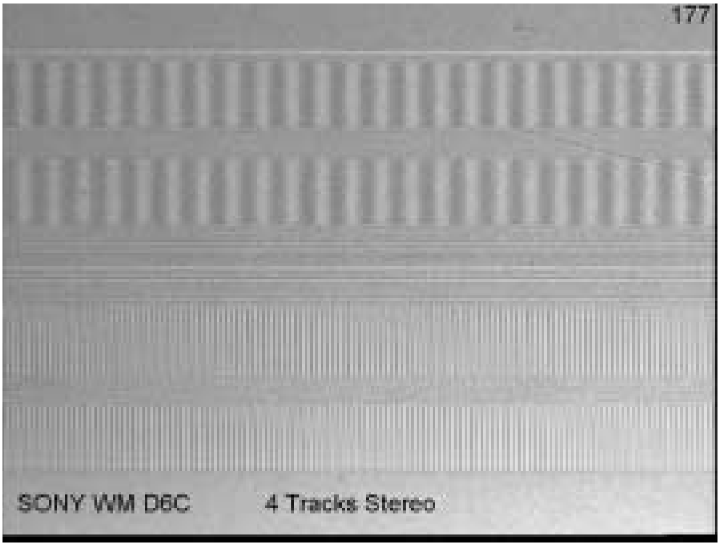

Plate 15 Stereo recording with Sony WM D 6C cassette recorder, 4 tracks, 2 tracks on each side, 180 Hz on side B, 1 kHz on side A. (Lower part of the picture).

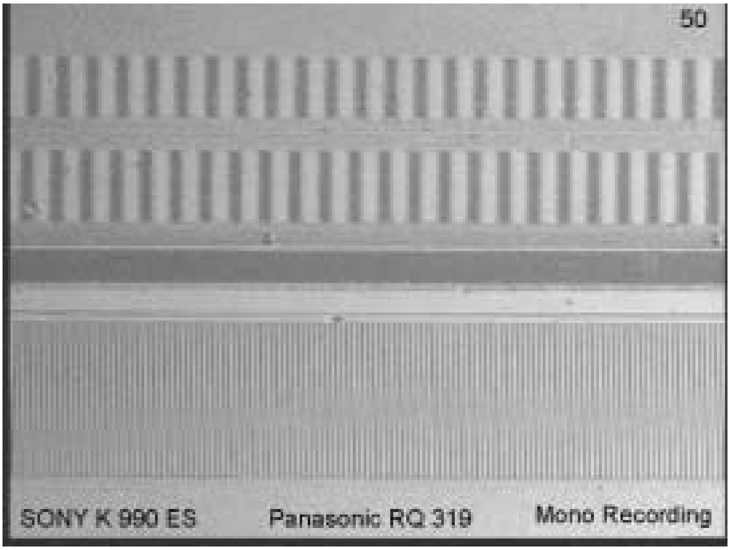

Plate 16 Stereo recording with Sony K 990 ES cassette recorder on side B, 180 Hz, mono recording with Panasonic RQ 319 on side A, 1 kHz.

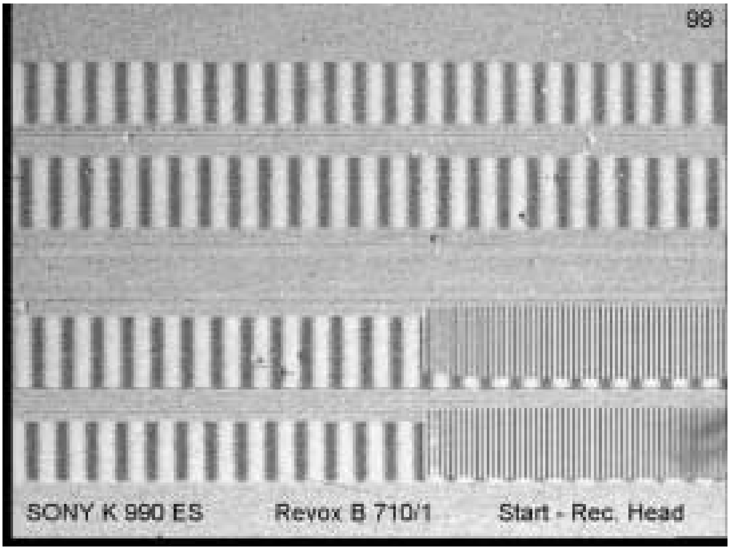

Plate 17 Stereo recording of a 180 Hz signal with sony K 990 ES cassette recorder on both sides of cassette, partially re-recorded on a Revox B 710 with a 1 kHz signal. Track position of the two machines differs visibly.

Plate 16 Side B (upper part) shows a signal which was recorded on the same recorder as the signal in Plate 14. Side A was over-recorded with a mono signal of 1 kHz on a Panasonic RQ 319 machine. It is a typical mono recording covering around half of the width of the cassette tape. Plate 17 presents an image of a tape that was pre-recorded on the SONY K 990 ES with a 180 Hz signal. Subsequently, a second recording (1 kHz) was made on side A with a Revox B 710 machine. The tracks of the new recording have a position slightly different from the previous one, so that remainders of the first recording are still visible.

Plate 18 shows a ‘start recording’ event of an Uher 1600 machine. The recording was made over the pre-recorded 180 Hz signal, which can still be seen on side B and as a residual signal ‘underneath’ one of the tracks on side A. This remainder disappears when the erase head is brought into contact with the audio tape. The recording head touches the audio tape at an earlier stage than the erase head – for that reason, there is always a space between the two heads where the recording has been started without the tape being erased beforehand. Another interesting peculiarity which can be seen on this picture is the narrow track between the two channels – in our experiments, this occurred only on the Uher 1600 machines.

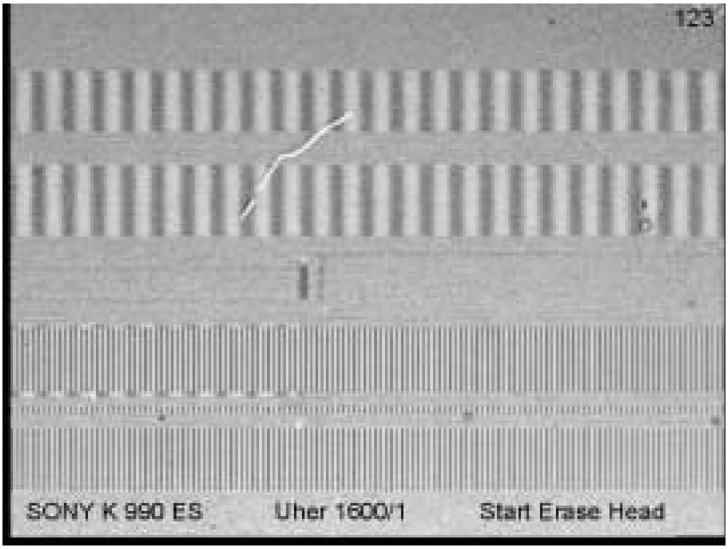

Plate 18 Stereo recording of a 180 Hz signal with Sony K 990 ES cassette recorder on both sides of cassette, partially re-recorded on side A with a 1 kHz signal on a Uher 1600. There is one narrow track between the two stereo tracks which is typical of the Uher 1600 machines. In the middle of the tape, between the two recorded signals, the “start recording” mark of the erase head can be seen.

Erase head marks

The erase head marks in Plates 19 and 20 have been produced when stopping a recording on the Panasonic RQ 319 machine. Their structure is typical of a permanent magnet type erasing head. Plates 21 and 22 show marks that have been produced on another cheap mono recording device, the Panasonic RX 1900. They are similar to the marks of the RQ 319 and show that the erase head of the RX 1900 is also a permanent magnet. Nevertheless, the marks of the RX 1900 can easily be distinguished from the marks produced on the Panasonic RQ 319. The differences are apparent in, among other features, the squared as opposed to rounded top right hand corner, the presence of a gap on the top edge of the head adjacent to the top right corner and the different patterning of the horizontal striations across the face of the head print.

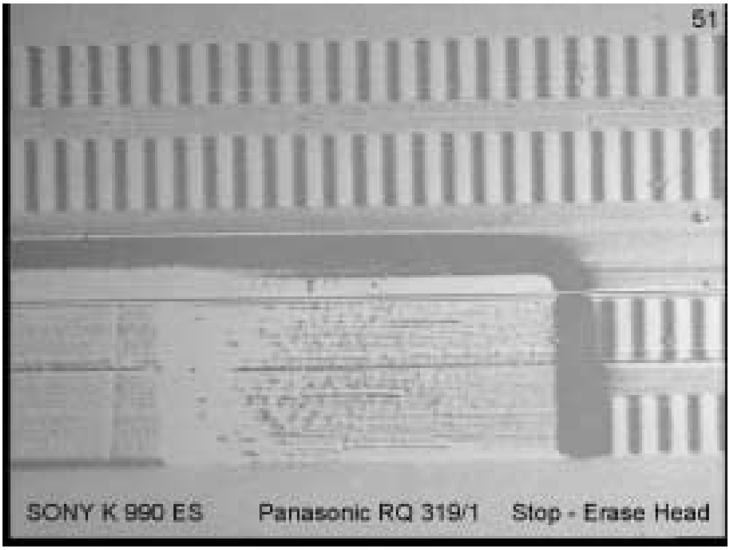

Plate 19 Cassette tape, again pre-recorded in stereo with 180 Hz on both sides on a Sony K 990 ES machine. Re-recorded on side A (lower part) on a Panasonic RQ 319 mono cassette recorder. Recording on side A stopped at the point shown in the picture. First of two stop events shown here.

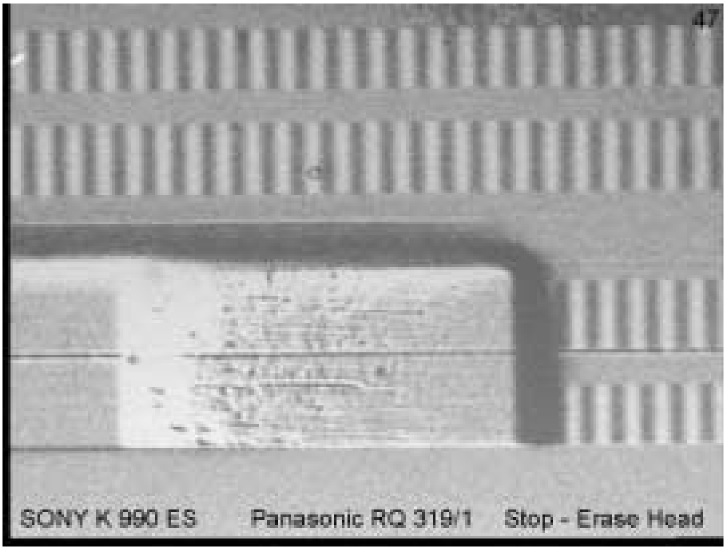

Plate 20 Same as plate 19, second out of two stop events shown here.

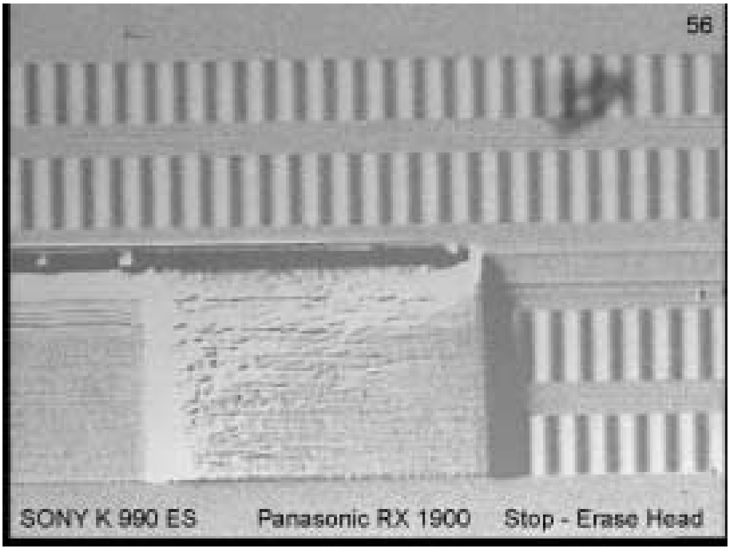

Plate 21 Same pre-recording as in plates 19 and 20 (Sony K 990 ES, stereo, 180 Hz), re-recorded on side A on a Panasonic RX 1900 mono machine. Stop mark of the erase head. First out of two stop events shown here.

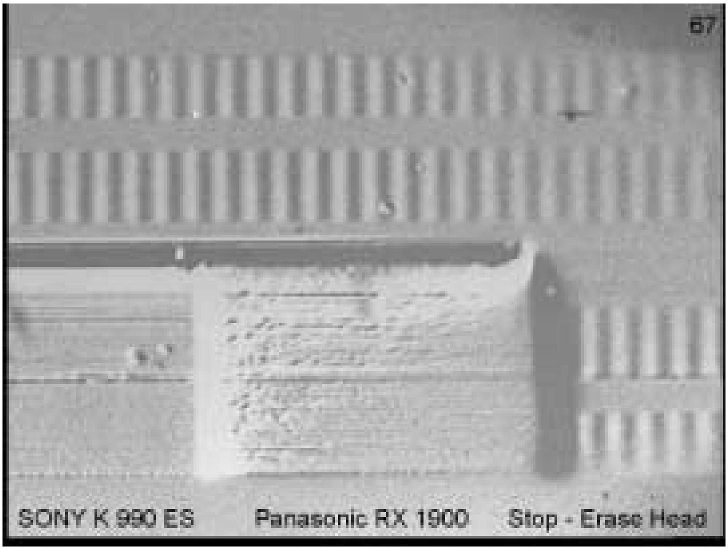

Plate 22 Same as plate 21, second of two stop events shown here

Plates 23, 24, and 25 represent instances of erase head activities of three machines of the same make and model – Uher 1600. The marks are similar but not identical. The second and third mark can hardly be distinguished in these general survey pictures – however, when zooming in on them, the differing details can be seen clearly. The tops of the two parts of the mark differ for these two machines. One of them shows hooks (Plate 26), the other (Plate 27) does not.

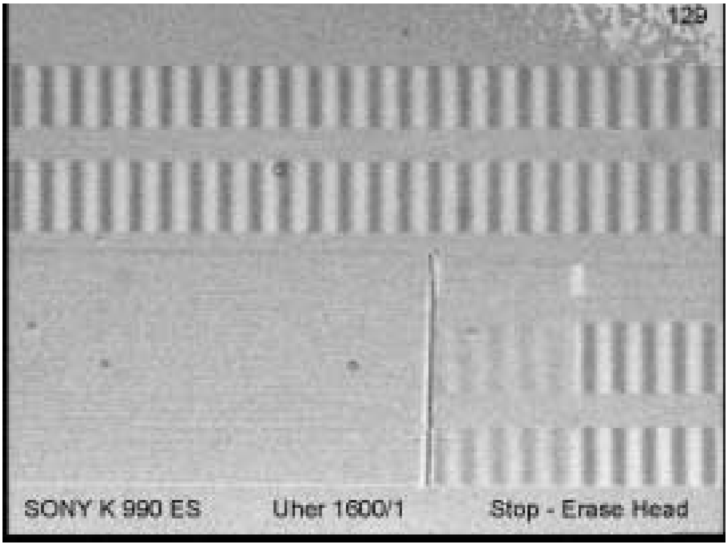

Plate 23 Same pre-recording as in plates 16 through 22, over-recording made on a Uher 1600, first of three different machines involved in the test. Mark of the erase head stop event.

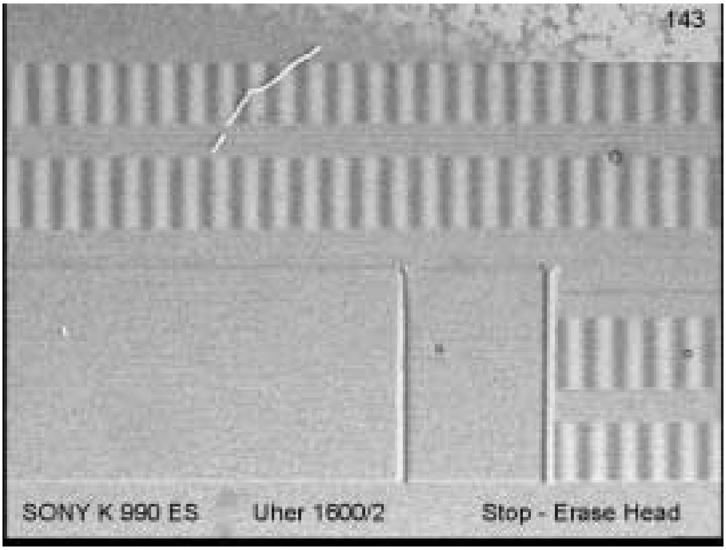

Plate 24 Same as 23, but using the second of three Uher 1600 machines involved in the test.

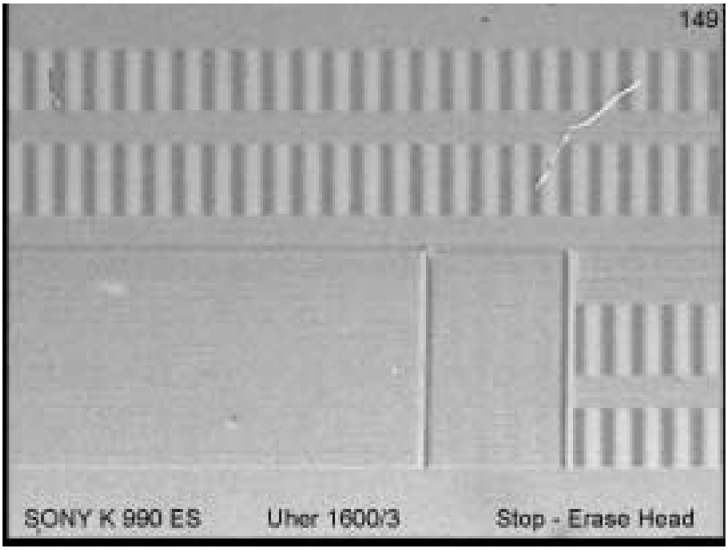

Plate 25 Same as 23 and 24, but using the third of three Uher 1600 machines involved in the test.

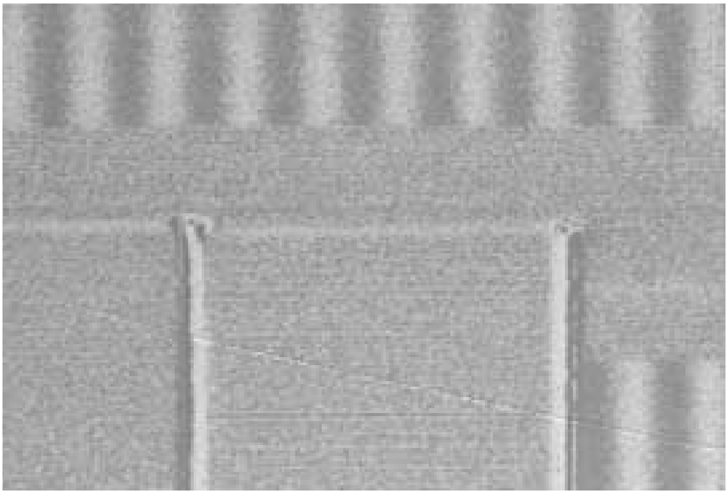

Plate 26 Zoom-in to the top of the erase head mark shown in plate 24.

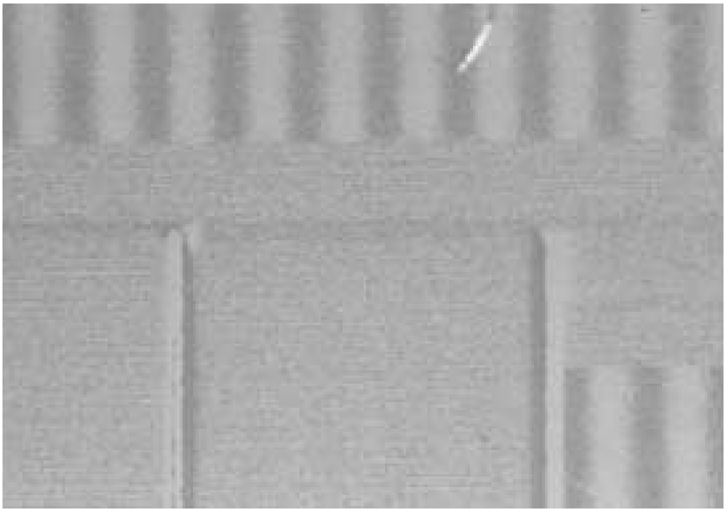

Plate 27 Zoom-in to the top of the erase head mark shown in plate 25.

These images represent only part of the results of our experiment. Indeed, all the stop marks (three for each machine) showed quite a consistent pattern for each of the individual recorders while varying within the different machines of the same brand and, of course, even more between completely different devices.

CONCLUSIONS AND OUTLOOK

A range of observations has been made on magneto-optical effects which are of considerable value in the forensic examination of tape recordings. The experiments that we conducted show that the crystals used here are suitable for visualization purposes. Each of the two types of crystals presented has particular advantages and should be chosen in part according to the questions to be solved by visualization. Intensity variations can best be shown with the type A crystal, whereas a very weak signal requires the type B crystal. The precise value of the visualization depends largely upon individual features of the recorders and the nature of the submitted recording. Parameters that may be visualized and that are not usually available through wave form analysis include track width and position, record head azimuth, distinctive electromagnetic head prints that are characteristic of switching into and out of the record mode, and permanent magnet erase head prints. Some features are common to many recorders, others tend to be unique to a particular recorder, and some may be dependent on the way the recorder is operated. Results suggest that in some cases magneto-optical analysis discloses what is virtually a fingerprint of the machine on which a recording was made. Further questions to be investigated mainly concern the stability or variability of those features. Factors that might influence them are the means of operating the recorders, operating temperature, wear and tear of the machine, vertical vs. horizontal position of the machine, recording speed, use of batteries, and others.

NOTE

1 Azimuth refers to the degree to which the recording head is aligned with the tape. Correct azimuth is a perfect perpendicular.

REFERENCES

Dean, D.J. (1989) *The Use of Ferrofluids in the Forensic Examination of Tape Recordings*, Home Office: Scientific Research and Development Branch.

Gusev, M. Yu., Grechishkin, R.M., Kozlov, Yu. F., and Neoustroev, N.S. (2000) ‘Linear analogue magnetic field micro imaging: Materials and technical implementation Izvestiya vysshykh uchebnykh zavedenii, Materialy elektronnoi tekhniki. (Higher school news, Electronics Materials), 1, 27–37 (in Russian).